

FINAL REPORT

I-90 Operations Study

May 2018



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Executive Summary

Interstate 90 (I-90) through the Spokane region was completed in 1974, and quickly became an essential transportation corridor for the region moving people and goods. As the region's population grew, traffic volumes increased on I-90. Higher traffic volumes, combined with crashes, construction work zones and other incidents increased the safety concerns and operational strain on I-90.

This project evaluated and prioritized transportation system management and operations (TSMO) solutions to improve safety along the I-90 corridor between Four Lakes and the Idaho Stateline (as shown in Figure 1). Targeting safety improvements also leads to operational improvements. If crashes and crash severity decrease, then delay for travelers decreases and travel time reliability improves. TSMO strategies target improving existing infrastructure rather than building additional capacity and tend to be lower cost than larger infrastructure projects. For example, instead of building an additional lane along I-90, a TSMO-type solution might use variable speed control or a queue warning system to help improve safety and mobility.

Figure 1. I-90 Study Area



The project began by evaluating the current safety and operational conditions along the corridor and identifying corridor needs. Then the project team reviewed and evaluated 31 concepts to address safety improvements along the I-90 corridor. After careful screening and a collaborative process with WSDOT staff, other public agencies, and open houses soliciting feedback from residents and business owners across the region, the project team prioritized three strategies to implement with current funding:



**Ramp
metering
system**



**Wrong way
notification
system**



**Queue/merge
warning
system**

Additionally, traffic incident management strategies and work zone management strategies will be advanced. A third dedicated responder was recently added, in part due to the evaluation completed in this study.

This report provides an overview of the evaluation process as well as the operational concepts for the strategies that will be implemented with the current funding.

Existing Conditions

The first phase of the project evaluated the current conditions along the corridor, mainly assessing the corridor characteristics, reviewing crash and incident data. The existing conditions analysis identified both safety and travel time reliability as the primary concerns for the I-90 corridor through the Spokane metropolitan region.

Study Area Length

30 miles

Posted Speed

70 mph (outskirts), 60 mph (MP 277-293)

(60 mph for trucks throughout)

Travel Time Reliability

Incidents are a growing cause of unreliable travel times on I-90. Over the last five years, unplanned incidents along the corridor increased by 40 percent. Incidents includes crashes along with other reported events such as disabled vehicles, debris on the roadway, and construction or maintenance events that disrupt the normal flow of traffic.

Traffic Volumes and Patterns

Traffic volumes on I-90 increased by more than 10% in each direction over the last four years, which contributes to decreased travel time reliability.

Traffic patterns have a distinctive peak travel direction. Westbound traffic volumes rise during the morning rush hour and eastbound volumes rise in the evening rush hour. Congestion and reliability issues are more likely to occur westbound in the mornings and eastbound in the evenings.

Roadway Characteristics and Traffic

Key roadway and traffic characteristics of the I-90 study corridor include:

Key Safety Findings

To address safety issues along the corridor, the project team needed to understand where the crashes were occurring, what caused them, the frequency of the crashes, and crash trends over time.

Crashes on I-90 steadily increased over the past five years.

Crashes increased 22 percent between 2012 and 2015 in the study corridor, and contribute significantly to non-recurring traffic congestion on I-90. These crash trends are shown in Figure 2.

Crashes occur daily on I-90.

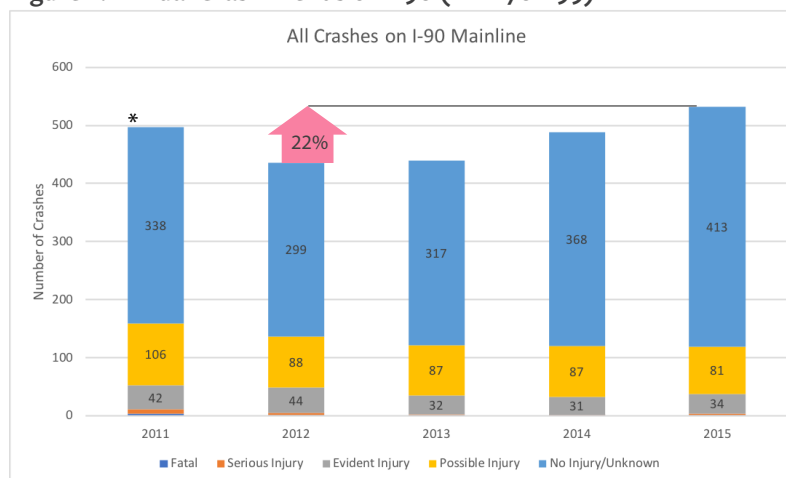
Between 2011 and 2015, the I-90 corridor experienced 3,699 crashes. (2,392 crashes on the mainline, and 1,307 crashes on on-ramps and off-ramps). The increasing number of crashes create unpredictable travel times for autos, transit and freight.

Crash Hot Spots.

Crashes are most frequent through

Spokane downtown area of I-90. Figure 3 shows the relative density of crashes along the I-90 study corridor.

Figure 2: Annual Crash Trends on I-90 (MP 270-299)



*Note that in 2011 there was an extensive rehabilitation project and a particularly high number of work zone crashes occurred, resulting in a higher than usual number of crashes for 2011.

While wrong way driver crashes are infrequent, they account for 38 percent of fatalities on I-90.

Between 2011 and 2015 there were nine wrong way driver crashes, three resulted in fatalities, and two resulted in severe injuries (12 percent of the total severe injury crashes).

Several segments along I-90, including on- and off-ramps, experience a higher than expected number of crashes based on the predictive (ISATe) crash analysis details provided in the Existing Conditions Memorandum. Contributing factors include closely spaced interchanges and short weave and merge areas. The ISATe analysis accounts for roadway geometry, and indicates a predicted number of crashes for segments. Areas with excess expected crashes highlight opportunities for operational improvements. The following segments had the highest percent of excess expected crashes:

- US 195 Interchange (WB and EB on-ramps) - 60% excess expected crashes
- Monroe to Division area (WB on-off aux lane Browne to Lincoln weave, EB Monroe on-ramp, EB aux lane Monroe to Division) - 44% excess expected crashes
- Freya Interchange area - 43% excess expected crashes
- US 195 to Monroe (WB Maple on-ramp, EB Walnut on-ramp, WB Monroe on-ramp) - 31% excess expected crashes
- Division Interchange area - 20% excess expected crashes

Weather and poor driving behavior contribute to the majority of I-90 crashes.

Inclement weather, exceeding a reasonably safe speed, and following too closely represent 84 percent of the contributing factors to crashes.

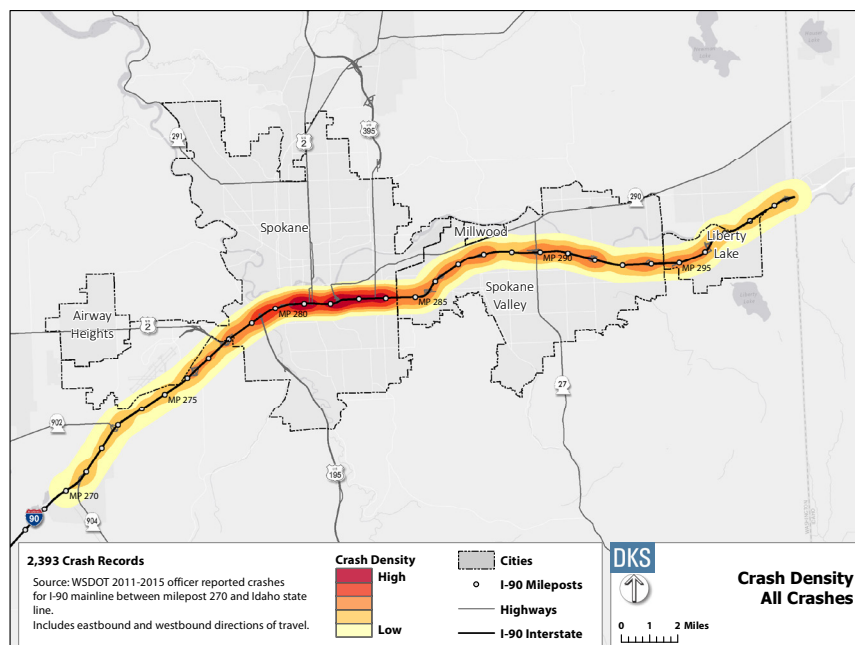
Rear-end, sideswipe and fixed object crashes occur most frequently on I-90.

Rear-end and sideswipe crashes make up 59 percent of total crashes between 2011 and 2015. Crashes with a fixed object are the third most common crash type accounting for 30 percent of the total.

Driving under the influence (DUI) is the leading cause of high severity crashes on I-90.

Close to 25 percent of all high severity crashes are DUI-related.

Figure 3: Crash Hot Spots, Mainline only (does not include crashes on ramps)



Key Needs

Through a collaborative effort with Washington State Department of Transportation (WSDOT) project staff, stakeholder outreach at the Study Advisory Group (SAG) workshop, a public open house, and online questionnaires to WSDOT eastern region staff, the project team learned about key needs across the corridor. The highest priority needs are shown in Table 1 and organized by operation area. A complete listing of the documented corridor needs is included in the Goals, Operations Objectives, and Needs Memorandum.¹

Table 1: High Priority Needs along the I-90 Corridor

OPERATION AREA	NEEDS IDENTIFIED
Traffic operations	<ul style="list-style-type: none"> • Reduce all crashes, especially high severity crashes • Optimize use of local roadway network and reduce use of I-90 for local trips • Improve transit travel time reliability • Reduce distracted driving • Improve ramp and merge area geometry that do not meet current performance expectations • Reduce queuing on I-90 due to off-ramps
Incident management	<ul style="list-style-type: none"> • Reduce incident clearance time • Expand WSDOT Incident Response Team (IRT) coverage • Develop traffic incident management (TIM) partnerships • Improve work zone management
Traveler information and performance data	<ul style="list-style-type: none"> • Coordinate traveler information systems between agencies • Educate travelers about current resources and improve utilization • Improve traveler information to public during special events



¹ I-90: Four Lakes to Stateline Operations Study. Goals, Operations Objectives, and Needs Memorandum. Prepared for WSDOT. Prepared by DKS Associates. February 2017.

Goals and Objectives

Goals and operations objectives were developed in coordination with the WSDOT project team and reflect input from the study's public engagement process and consideration of findings from the existing conditions analysis. Three key goals and related objectives emerged from this effort.

GOAL 1

Improve safety performance for all I-90 corridor users

OBJECTIVES

- Meet Washington State Safety Plan Target Zero goals of zero traffic fatalities and serious injuries by 2030.
- Reduce weather-related crashes.
- Reduce rear-end crashes.
- Reduce pedestrian and bicycle crashes at ramp terminals.

GOAL 2

Enable efficient management and operations of the I-90 Corridor

OBJECTIVES

- Improve clearance times for all lane blocking incidents.
- Improve construction and maintenance work zone management policy.
- Improve coordination between agencies and districts that maintain, operate or respond to incidents or planned events along the facility.
- Improve travel time reliability along the corridor.

GOAL 3

Enhance traveler information along the I-90 Corridor

OBJECTIVES

- Communicate real-time road conditions to travelers using any mode (passenger vehicle, freight, or transit).
- Enhance available pre-trip and en-route traveler information.
- Provide information about planned events or work zones that impact travel at least 24 hours prior to the occurrence.



Screening Process

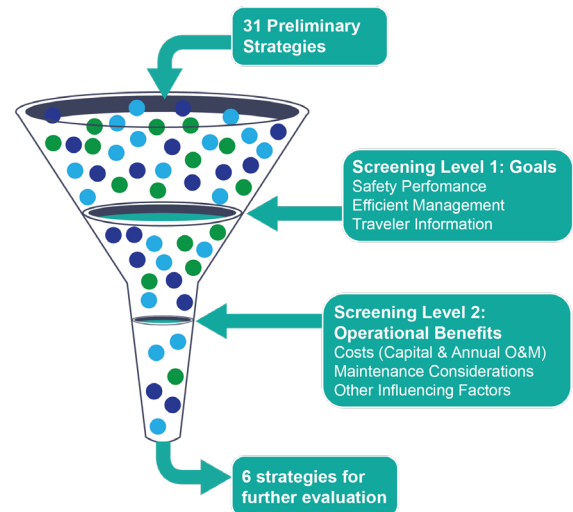
The project team filtered the full toolbox of TSMO strategies through two levels of screening to identify which strategies offer the best potential to improve safety and operations along the corridor. The detailed screening process is available in the *Evaluation and Screening Memorandum*.²

Screening Levels 1 and 2

The first level screening narrowed strategies based on how well they achieved the three goals (see previous page) for managing the I-90 corridor between Four Lakes and the Idaho Stateline.

The second level screening ranked the remaining strategies based on:

- Potential for operational benefits (such as reducing crashes)
- Feasibility to implement based on physical factors, institutional factors, and operational and maintenance factors
- Implementation cost
- Annual operations and maintenance costs



Out of this screening process the top six strategies to advance for further evaluation included:



ACTIVE TRAFFIC MANAGEMENT Install variable message signs (VMS) and weather sensors along the freeway to provide variable speeds notifications, queue warnings, and dynamic lane management.



RAMP METERING Install ramp meters at on-ramps to manage the flow of entering vehicles, reduce crashes at merge areas, and minimize congestion on the mainline.



WRONG WAY DRIVER NOTIFICATION SYSTEM Install sensors on off-ramps that can detect wrong-way drivers and alert the traffic management center and travelers using VMS or, when possible, on-board navigation systems.



TRAFFIC INCIDENT MANAGEMENT (TIM) STRATEGIES Enhance existing traffic incident management strategies by further developing TIM Teams, expanding the Incident Response, and establishing instant tow contracts.



WORK ZONE MANAGEMENT Implement work zone management strategies that improve safety in work zones. These strategies apply safety measures that inform drivers of work zone and worker locations, limit work zone hours, and support a range of work zone durations from long-term stationary projects to short duration or even mobile projects.



RAMP CLOSURES Close on-ramps or off-ramps either permanently or by time of day to reduce crashes where ramp spacing does not meet performance expectations. This study only evaluates ramp closures from the perspective of reducing crashes. Further evaluation in the form of an Interchange Justification Report (IJR) is necessary before proceeding with this strategy. An IJR would explore the traffic operational impacts, socio-economic impacts, and political factors associated with a closure. This initial evaluation is intended to determine whether further study at a location may be warranted.

² I-90: Four Lakes to Stateline Operations Study. Evaluation and Screening Memorandum #4. Prepared for WSDOT. Prepared by DKS Associates. March 2017.

Further Evaluation - Benefit Cost Analysis

The project team performed a benefit cost analysis for each of the six strategies identified for further evaluation. The benefit cost analysis determined both an annualized cost and annualized benefit for each strategy:

Annualized Cost

The annualized cost incorporated three elements: capital cost, service life and annual operations, and maintenance costs. Expected service life ranges from 5 to 25 years depending on the equipment or software.³ The service life accounts for expected replacement cycles within that 25-year outlook.



Annualized Benefit

The annualized benefit focused mainly on the potential for each strategy to reduce crashes. Other benefits such as reducing delay, emissions, or improving operational efficiency are not included in the benefits calculation. In Washington, each type of crash severity is associated with a cost, as shown in Table 2.

Table 2: WSDOT Crash Severity Cost

CRASH SEVERITY	ASSOCIATED COST (WSDOT)
Fatal	\$2,900,000
Disability Injury	\$2,900,000
Evident Injury	\$155,000
Possible Injury	\$60,000
Property Damage Only (PDO)	\$10,000

To determine the monetary benefits associated with a strategy, the project team used case studies and research to estimate how each strategy could reduce crashes along the corridor, and then applied that reduction to the actual distribution of crash severities.



³ Expected Service Life estimated based on WSDOT Safety BC Analysis 2019-2021 Safety Scoping and FHWA TOPS-BC tool.

Evaluation Results and Implementation Recommendations

This section provides a summary of the six strategies including a description of how the strategy functions, the benefit cost evaluation results, and recommendations. For the three strategies that advanced as part of the initial funding (called Phase 1 and indicated with * in the table below), this section includes some of the design and operational recommendations from the *Operational Concept*⁴.

	STRATEGY	BENEFIT COST RANGE	RECOMMENDED PHASING
*	 Ramp Metering Install ramp meters at on-ramps to manage the flow of entering vehicles, reduce crashes at merge areas, and minimize congestion on the mainline.	5.6 to 7.9 Full System –13 ramps	Phase 1: 6 ramps (see Ramp Metering section for details)
*	 Wrong Way Driver Notification System Install sensors on off-ramps that can detect wrong-way drivers and alert the traffic management center and travelers using VMS or, when possible, on-board navigation systems.	1.6 to 2.8 Depending on Segment	Phase 1: 13 off-ramps (see WWD Notification System section for details)
*	 Active Traffic Management Install variable message signs (VMS) and weather sensors along the freeway to provide variable speeds notifications, queue warnings, and dynamic lane management.	4.2 to 6.3 Variable Speed System	Phase 1: Merge warning sign for US-195 EB ramp and/or queue warning upstream of WB Division off-ramp. Later phases may include variable speeds or additional VMS and queue warning
	 Traffic Incident Management (TIM) Strategies Enhance existing traffic incident management strategies by further developing TIM Teams, expanding the Incident Response, and establishing instant tow contracts.	4.4 to 15.4 Instant Tow 3.9 to 9.1 Dedicated Responder	Phase 1: Additional dedicated incident responder (already implemented)
	 Work Zone Management Implement work zone management strategies that improve safety in work zones.	N/A	Phase 2: as funding becomes available
	 Ramp Closures Close on-ramps or off-ramps either permanently or by time of day to reduce crashes where ramp spacing does not meet performance expectations. <i>Note:</i> This study only evaluated ramp closures from the perspective of reducing crashes. It did not consider socio-economic impacts, which would be the next step in the evaluation.	1.3 to 8.3	Not proceeding with this strategy at this time. A full Interchange Justification Report (IJR) will be necessary before proceeding

⁴ I-90: Four Lakes to Idaho State Line Operations Study – Operational Concept. Prepared by DKS Associates. March 2018.



Ramp Metering

Description

Traffic signals on freeway ramp meters alternate between red and green to control the flow of vehicles entering the freeway. Metering rates can be adaptively altered based on freeway and on-ramp traffic conditions. Ramp meters perform best when installed in groups along the corridor instead of isolated installations. Installing ramp meters in groups allows for downstream ramp meters to be more proactive and change ramp meter rates to help mitigate upstream congestion.

Benefits Summary

Ramp metering can reduce crashes on the mainline by as much as 36 percent, and ramp metering projects typically yield high benefit to cost (B/C) ratios that range from 2 to 10. In fact, for the 13 locations along the I-90 corridor (from US 195 to Freya) analyzed, the estimated B/C ratio ranged from 6.4 to 9.6, reducing up to 14 crashes per year.

Average Annual Benefit: \$1,775,000

Cost Summary

Initial Capital Cost: \$3,500,000

Annual O&M: \$55,000

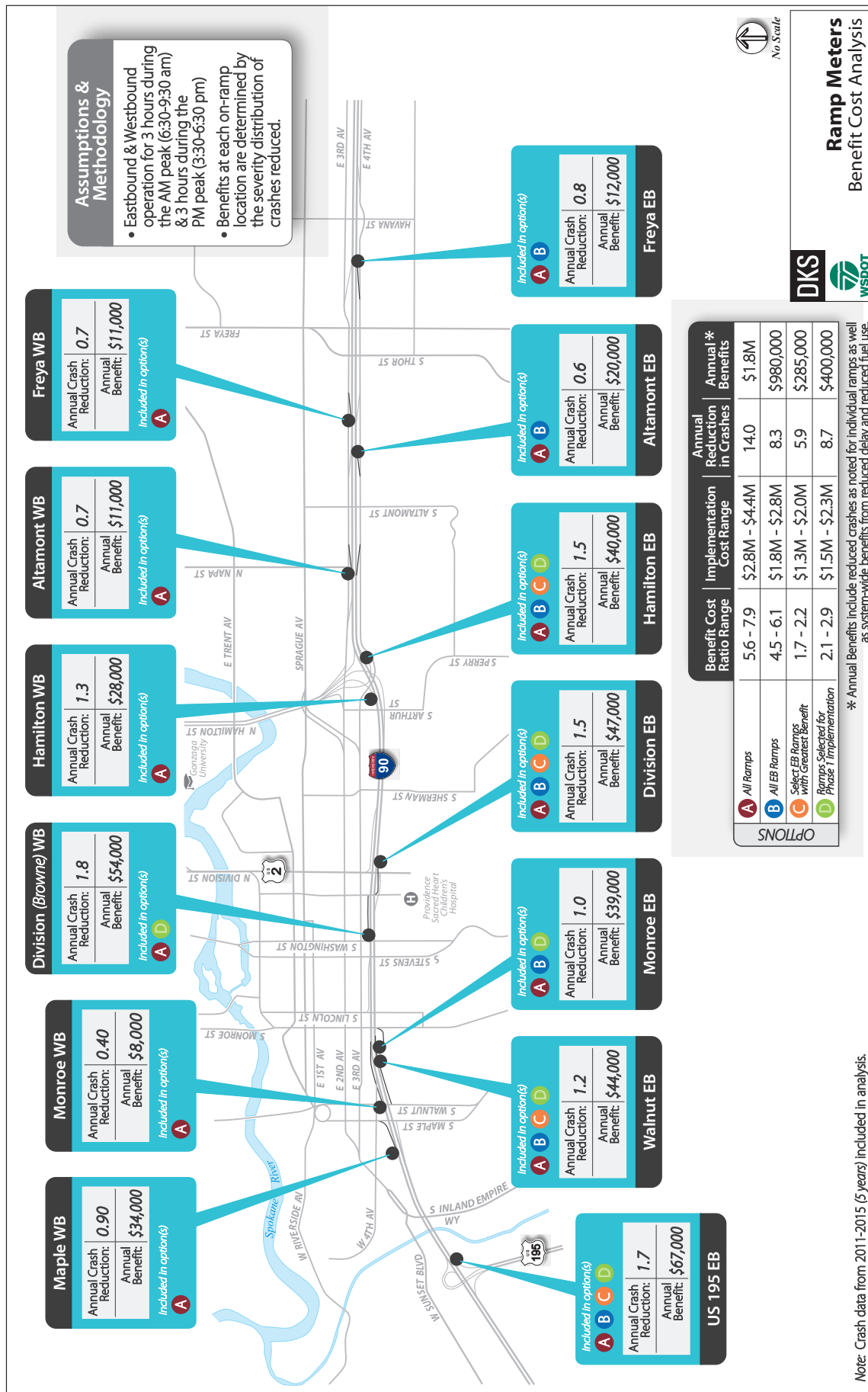
Average Annual Cost (over the lifetime of the project): \$270,000

Benefit-Cost Range

5.6 to 7.9 (13 on-ramps through downtown core)

Benefits are likely underestimated, as ramp meters can work in conjunction with other strategies, including ATM and a Wrong Way Notification System. The benefits calculated for this study assume ramp meters are active during peak hours. If ramp meters are activated during other incidents or events, the scale of benefits will increase.

Figure 4: Ramp Meter Benefit Cost Results



Recommended Locations

The project team recommends ramp meters at six on-ramps through the downtown area:

EASTBOUND	WESTBOUND
EB US 195 on-ramp	WB Division/Browne on-ramp
EB Walnut on-ramp	
EB Monroe on-ramp	
EB Browne/Division on-ramp	
EB Hamilton on-ramp	

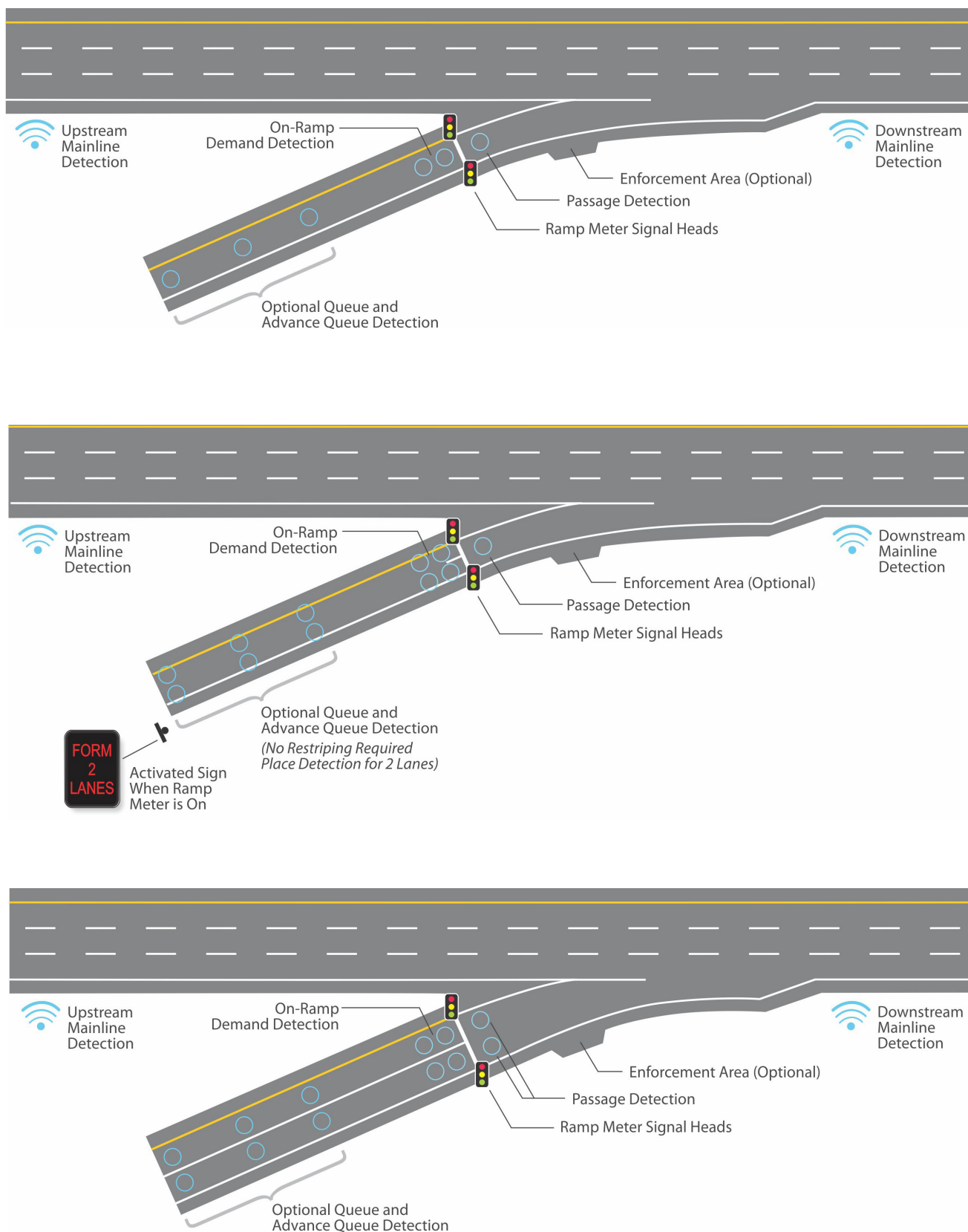
Operations

Modes of operations for ramp meters include a range of functionality from a basic time of day type of programming to a system that uses detection to change the ramp meter rate in real time using a system-wide approach. The ramp meters would operate through the Spokane Regional Traffic Management Center (SRTMC). SRTMC currently operates the iNET advanced traffic management software (ATMS). With the current software SRTMC could operate time of day ramp metering functions, or add a module to operate an adaptive ramp metering system.

The Operational Concept takes an in-depth look at the operations specific to each on-ramp, evaluating the necessary rate to minimize impact to adjacent local streets, and how to effectively operate each ramp at the desired rate. Table 3 outlines the four different vehicle release methods, and Figure 5 illustrates the design of a single lane, single retro-fit lane, and dual lane ramp meter system. A single lane retro-fit is striped as a single lane on ramp, and operates as a single lane unless the ramp meter system is on. When the system is operating a sign is activated at the upstream end of the ramp instructing vehicles to form two lanes.

Ramp Metering Release Method	Maximum Hourly Capacity (Vehicles)
Single Lane – One Vehicle per Green	900
Single Lane – Two Vehicles per Green	1200
Two Lanes – Alternating Greens	1400
Two Lanes – Tandem (simultaneous) Greens	1700

Figure 5. Typical design layouts for a single lane ramp meter (top), a retro-fit single to dual lane ramp meter (middle), and a dual lane ramp meter (bottom)



Proposed Configuration and Metering Rates

The ramp meter control cabinet is typically positioned so that maintenance personnel can observe the signal indication and see the controller face, allowing a single person to observe the complete installation when in operation.

In the event that the vehicle queue extends beyond the available ramp storage space, detection can be placed at the upstream end of the ramp and trigger a queue release if that operation feature is desired.

Based on the queuing analysis and existing geometry at each on-ramp the project team provided design and operation recommendations for each on-ramp, as shown in Table 4. A more in-depth discussion of the ramp meter operations and design layout recommendations are described and illustrated in the *Operational Concept*⁵.

Table 3: Ramp Meter Recommended Operations

RAMP LOCATION	RECOMMENDED OPERATIONS
EB US 195 On-Ramp	Retrofit single lane ramp to a two-lane on-ramp during ramp metering and use alternating green release (maximum throughput = 1400 vehicles per hour). Consider a downstream enforcement or monitoring pad.
EB Walnut Street On-Ramp	Two-Lane ramp meter with tandem release (maximum throughput = 1700 vehicles per hour).
EB Monroe On-Ramp	Single lane ramp meter with one vehicle per green (maximum throughput = 900 vehicles per hour).
EB Browne (Division Street) On-Ramp	Two-Lane ramp meter with tandem release (maximum throughput = 1700 vehicles per hour).
EB Hamilton On-Ramp	Retrofit single lane ramp to a two-lane on-ramp during ramp metering using alternating greens (maximum throughput = 1400 vehicles per hour).
WB Browne (Division Street) On-Ramp	Single lane ramp meter with two vehicles released per green (maximum throughput = 1200 vehicles per hour).

⁵ I-90: Four Lakes to Idaho State Line Operations Study – Operational Concept. Prepared by DKS Associates. March 2018.



Wrong Way Driver Notification System

Description

The purpose of the wrong way driver (WWD) notification system is to alert drivers that they are entering the freeway in the wrong direction to allow for self-correction prior to entering the freeway ahead. If the driver does not self-correct, then messages can be displayed to inform right way drivers and allow them to make decisions to minimize their risk, while also informing TMC operators and law enforcement (called “Full Response Mode”). Figure 6 illustrates aspects of each operation mode. The wrong way driver notification system consists of detection (e.g., loops, radar, or video), video capture, warning signs (many different designs most utilizing red LED indications) and freeway entry detection, as well as improvements to signing and pavement markings.

One challenge to installing a wrong way notification system is determining where drivers are accessing the freeway the wrong way. Crash reports indicate where the crash occurred, but are unlikely to indicate where the driver entered the freeway. Without fully understanding where drivers access the freeway, a systemic approach to installing the WWD notification system is recommended. To help prioritize locations along the corridor, evaluating interchange geometry is also recommended. In some cases the interchange and adjacent roadway geometry may increase the likelihood of a driver accessing the interstate in the wrong direction, in which case those locations may be prioritized.

Benefits Summary

While wrong way driving (WWD) incidents are infrequent, accounting for less than one percent of the crashes on I-90 (nine crashes total between 2011 and 2015), when wrong way crashes do occur, the results are severe. Data shows that wrong way collisions have a 12 to 27 times higher fatality rate than other types of crashes. Wrong way driver crashes on I-90 resulted in three fatalities, or 38 percent of the total fatalities along the corridor. All nine of the wrong way crashes on I-90 over the study period are shown in Figure 7.

Reviewing additional data from the Washington State Patrol (WSP) system, data from 2017 indicates that far more WWD events occur than are reported in the crash database, since not all WWD events result in a crash.⁶ In 2017, 21 WWD events were reported to WSP within the I-90 study area. One of which resulted in a fatality, while the other 20 WWD incidents resolved without a crash. The higher than reported number of WWD events in the crash database, combined with the potential to result in severe crashes, reinforce the need to address this issue.

Wrong way notifications systems can reduce wrong way crashes by over 40 percent. In San Antonio the number of wrong way driver reports fell from 269 to 162 in the five years since the WWD notification system was installed; and in Rhode Island and Florida’s turnpike system 99 percent of detected wrong way drivers self-corrected after the WWD notification system was installed.⁷

Average Annual Benefit: \$890,000 (full corridor)
\$350,000 (funded segment)

Cost Summary

Initial Capital Cost:

\$6,200,000 (full corridor)
\$3,000,000 (funded segment)

Annual Operations and Maintenance:

\$10,000 to \$25,000

Average Annual Cost:

\$410,000 (full corridor)
\$180,000 (funded segment)

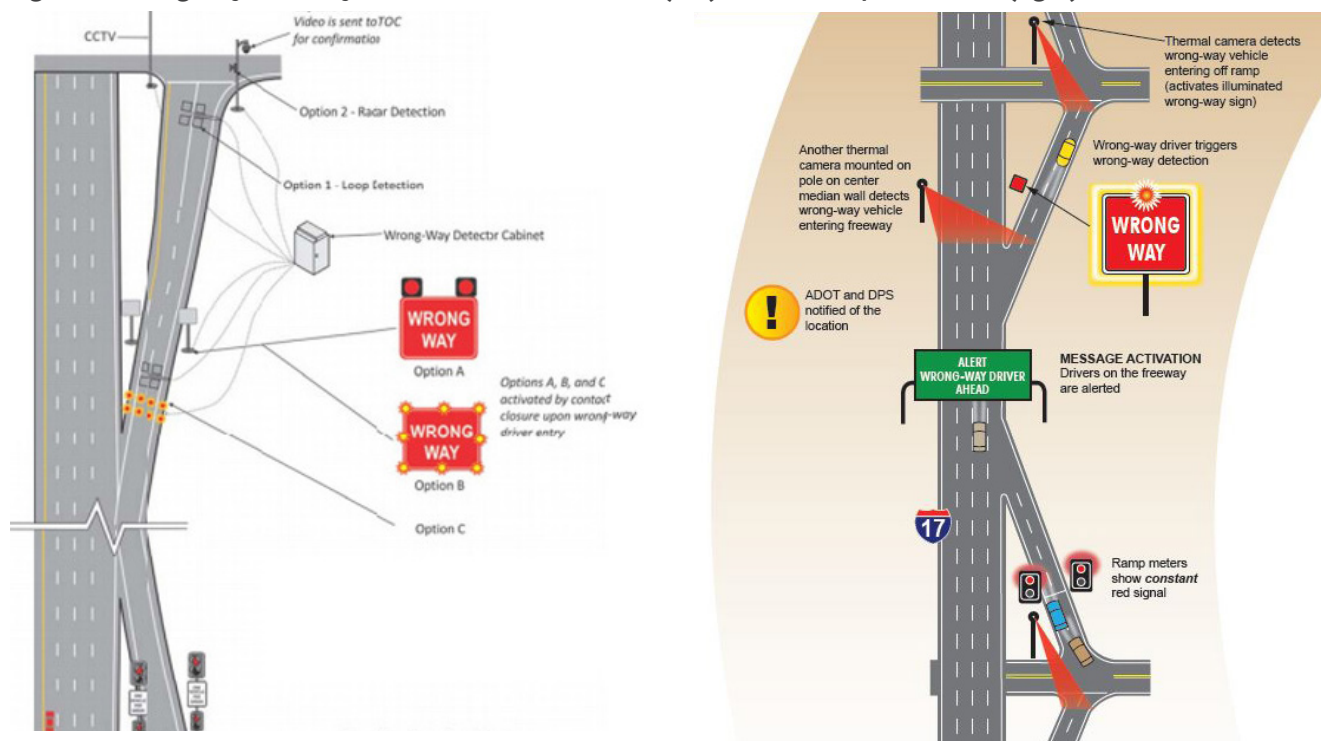
Benefit Cost Range

1.8 to 2.8 (full corridor); 1.6 to 2.5 (funded segment)

6 Washington State Patrol, Research, Analysis, and Mapping (RAM). APA 19: 2017 Wrong Way Incidents on I-90 (MP 279-299). Prepared Jan 8, 2018.

7 Article: <http://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2017/12/19/technology-is-turning-wrong-way-drivers-around>, Dec 19, 2017. Accessed Jan 2018.

Figure 6. Wrong Way Driver Systems – Self Correct Mode (left) and Full Response Mode (right)




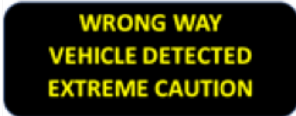
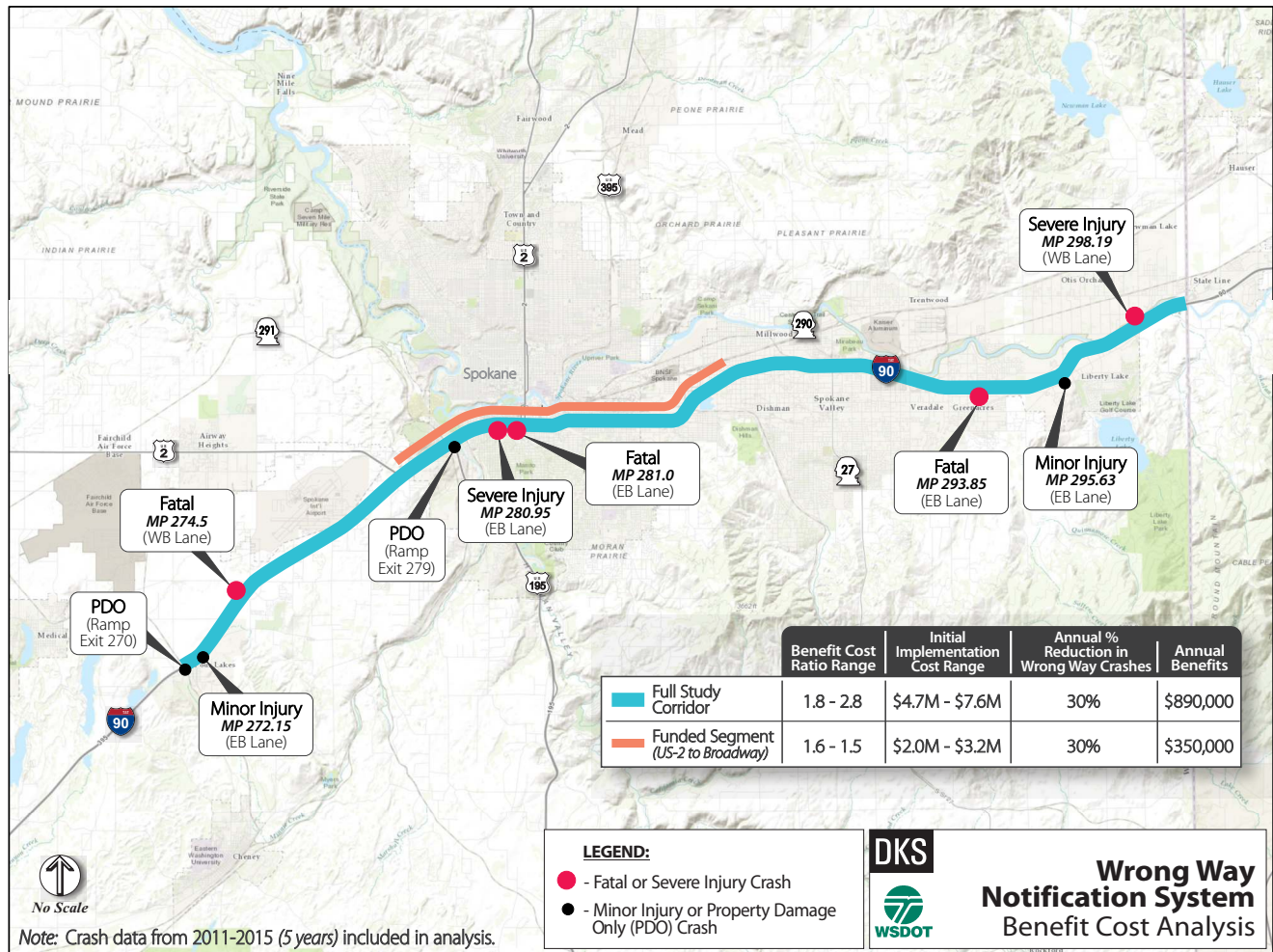
CONCEPT	DESCRIPTION
<p>Driver Self-Correction Mode</p> 	<p>System detects a vehicle entering the ramp and immediately activates the alert messaging signs. The flashing red LED's and wrong way sign catch the driver's attention, and the driver pulls over to the shoulder and quickly and safely executes a "U-turn".</p> <p>Low cost options include:</p> <ul style="list-style-type: none"> • Install wrong way arrows on exit ramps • Lower the mounting height of WRONG WAY and DO NOT ENTER signs • Add red retroreflective sheeting on sign supports • Install pavement markings to improve channelization • Consider improved signing and channelization at access points where drivers can more easily access the freeway the wrong way.
<p>Full Response Mode</p> 	<p>System detects a WWD and notifies right way drivers, TMC operators, and law enforcement. When a vehicle is detected entering the freeway in the wrong direction, travel alerts could automatically be sent out from the controller. The alert could also be sent to law enforcement dispatch services, operators at the TMC, and possibly integrated into other operational systems, such as the ramp meter systems for holding of traffic and/or confirmation of the wrong way vehicle's location.</p>

Figure 7. Wrong Way Crashes on I-90 (2011-2015)



Recommended Locations

Install a WWD notification system at 16 off-ramps between Walnut and Sprague:

EASTBOUND

EB Walnut off-ramp
EB Division off-ramp
EB Hamilton off-ramp
EB Altamont off-ramp
EB Freya off-ramp
EB Sprague off-ramp
EB Broadway off-ramps

WESTBOUND

WB Freya off-ramp
WB Altamont off-ramp
WB 2nd Avenue off-ramp
WB Hamilton off-ramp
WB Division off-ramp
WB Lincoln off-ramp
WB Maple/Walnut off-ramp
WB Broadway off-ramp
WB Sprague off-ramp

Operations

There are two levels of design to consider for the WWD notification system: the driver self-correction mode and the full response mode. The two modes are compatible and can build off one another, being constructed in phases if necessary.

For the full response mode, ATMS integration and communication is necessary. ATMS integration can be accomplished via multiple methodologies depending on the objectives and user requirements. The wrong way driver notification system will at a minimum require integration for activation of the variable message sign (VMS) messaging. Beyond the basic integration for VMS messaging will be dependent on the other systems existing integration and the capabilities of the existing ATMS software. This system software module may be available as a stand-alone module and use of a tested module may be a better solution if it exists from the potential vendors.

Integration with law enforcement agencies may also help to minimize the exposure time to the potential wrong way vehicles. This can be accomplished through integration with the ATMS system or potentially a more fault tolerant methodology would be directly from the controller cabinet via a contact closure upon activation of the full response mode.

Design Recommendations

Central to the wrong way driver detection is the inclusion of two zones of detection. Both zones must maintain a high level of reliability for the system to function effectively. Any detection technology can be deployed in these zones, but careful consideration should be given to the weather conditions typical for the area and the condition of the pavement.

The system components are positioned with a detection zone near the exit of the off ramp (providing initial detection of the wrong way vehicle), a warning sign positioned on the ramp such that the driver can see and understand the message before they would pass it, and a detection zone at the beginning of the ramp near the gore point for detecting entrance onto the freeway.

A short slip ramp, present at a few locations along the I-90 corridor, could present design challenges for the implementation of wrong way driver notification system. With short slip ramps the period of time between detection and entry onto the freeway is very short. It would be helpful for these locations to have a warning sign with integrated detection be used for the initial “driver self-correction mode” detection. Another design consideration is the detection of vehicles traveling along the parallel frontage road as entering the freeway off ramp. Careful screening of the detection technology will be required to ensure false positive detections are avoided or minimized.

As with all design features related to the wrong way driver notification system, maintenance and reliability of communications from the field elements will be critical to assuring system operators that the system will function properly in the event detection takes place. The use of radio communication, as required for many of the installations, will need to be monitored by the system to assure that the link remains open at all times. The use of direct fiber or leased service connections is preferred over radio communication where available.



Active Traffic Management

Description

Active Traffic Management (ATM) uses a combination of operational strategies to optimize the existing infrastructure and improve safety. On I-90 the primary strategies include a variable speed system, queue warning, travel times, and dynamic lane control.

Speed and lane control information are conveyed to travelers using signs installed over each lane. The system could also provide weather, travel time, and queue warning information to travelers based on real-time measured conditions using full matrix Variable Message Signs (VMS).



A queue or merge warning system is part of the active traffic management (ATM) strategy to reduce rear-end collisions and reduce congestion. A queue warning system is typically deployed to alert motorists to queuing

conditions ahead. With advance warning, drivers can slow down and possibly avoid crashes. This system will use the existing electronic message signs on the corridor and three new electronic signs at specific locations to target areas where vehicle queues and merging issues are most frequent along the I-90 corridor. The installations typically incorporate an electronic message board (referred to as a variable message sign, or VMS), and a detection system with software to determine the existence of a vehicle queue. A message that is pre-approved for the condition will automatically activate and de-activate as queues form and dissipate.

Active traffic management was initially evaluated as a bundle of variable speed limits (VSL) and variable message signs (VMS) that could operate as a merge warning system or queue warning system. Ultimately the cost of installing a full VSL system along the corridor was beyond the available funding, so the strategy evolved to address the eastbound merge issue at the US-195 on-ramp.

This section provides an overview of the full active traffic management concept, as well as the recommended operations of the narrower focus on the merge warning system.

Benefits Summary

Variable Speed System is associated with an 8% crash reduction, potential to reduce approximately 100 crashes per year through the proposed project limits on I-90.

Queue Warning System

- 16% rear-end crash reduction resulting in injuries (CMF ID 76).
- 16% increase in rear-end crashes resulting in PDO (CMF ID 77)

Average Annual Benefit: \$6,000,000 (variable speed system benefits only)

Cost Summary

Initial Capital Cost:

\$24,000,000 (full system – 10 gantries)

\$1,000,000 to \$2,500,000 per gantry if installed individually

Annual Operations and Maintenance:

\$105,000

Average Annual Cost: \$1,200,000

Benefit Cost Range

4.2 to 6.3* (Benefits due to the Variable Speed System)

*Additional benefits possible if the system is also used for queue warning or traveler information

Figure 8. Active Traffic Management Benefit Cost Analysis



Recommended Location

Install a merge warning system at the merge area of US-195 onto eastbound I-90.

The full bundle of active traffic management exceeded available funding for this project, so a component of ATM is recommended to address a known high crash area along the corridor. The merge from US-195 northbound to I-90 eastbound is short, creating a safety and operational hazard for travelers through this area. Currently, there is a guide sign about a ¼ mile in advance of the merge and a static warning sign with flashing beacons just prior to the merge that is activated by traffic on the on-ramp (as pictured in Figure 8). Both signs are intended to alert motorists and encourage use of the left lane for through traffic, however, WSDOT expressed there is low conformance to the signs.

Figure 9: Existing Merge Area Treatment Upstream of the US-195 Merge



Operations

In advance of the US-195 merge with eastbound I-90, VMS could be used to actively warn through travelers to move to the left lane when there is traffic on the US-195 on-ramp. VMS, compared to the current static signs (and static sign with flashing beacons), could better catch the attention of drivers and more effectively encourage drivers to use the left lanes through the merge area, leaving the right lane open for traffic from US-195. The current signs don't provide specific instruction to move left, but provide information then left for the traveler to interpret and make decisions.

As part of the evaluation, the project team also explored the option of dynamic lane management, with the intent of closing the right most lane upstream of the merge area. In this case the dynamic lane use would require drivers to move as indicated, instead of just encourage drivers to move left. However, due to expected growth to the area and an expected increase in traffic volumes, the useful life of that strategy was concerning to agency officials and is not recommended.

Design Recommendations

The VMS could be placed upstream of the merge either on their own sign structure or on existing overpasses, which may reduce the construction cost. Instead of the current static signs, these VMS could activate based on the US-195 on-ramp volumes.



Traffic Incident Management

Description

Traffic incident management (TIM) systems can reduce the effects of incident-related congestion, reduce secondary crashes, and keep first responders safe by decreasing the time to detect incidents, the time for responding vehicles to arrive and clear the incident, informing approaching drivers, and providing a safe scene. Ultimately, clearing incidents faster reduces secondary crashes and the time required for traffic to return to normal conditions.

TIM should be implemented on a region-wide basis with focus on I-90 and other key state routes. For I-90, the TIM strategies evaluated included:

- **Expanding the the WSDOT Incident Responder Team (IRT)** – providing dedicated response vehicles and staff that routinely patrol WSDOT facilities and assist travelers in need.
- **Establishing instant tow contracts** – an instant tow contract allows incidents to be cleared faster, by providing a payment agreement between WSDOT and select tow agencies to respond to an incident before law enforcement of WSDOT staff confirms the incident. If a tow is not needed, the tow company is paid a flat fee, and if a tow is needed, the driver pays the expense.
- **Developing a TIM team for the region** – establish regular meetings and after-incident reviews between first responders in the region to help build relationships, improve response practices, and open communication.

Benefits Summary

Applying FHWA TOPS BC methodology,

- Passenger vehicle delay reduction: 7,000 / 28,000 vehicle hours per year
- Truck vehicle delay reduction: 500 / 2,100 vehicle hours per year
- Secondary incident reduction: 2.4 / 9.0 fewer crashes per year

Cost Summary

Initial Capital Cost: \$0 / \$0*

Annual Operations and Maintenance: \$24,000 (Instant Tow)
\$135,000 (Dedicated Responder)

Average Annual Cost: \$24,000 (Instant Tow)
\$135,000 (Dedicated Responder)

Benefit Cost Range

4.4 to 15.4 (Instant Tow); **3.9 to 9.1** (Dedicated Responder)

*No capital cost because the Eastern Region has an available incident response truck.

Recommendations

Add a third dedicated incident responder and vehicle to the WSDOT fleet. *(Already implemented).*



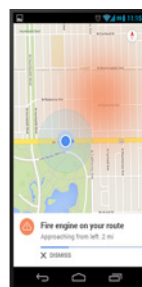
Work Zone Management

Description

Work zone management addresses work zone policies and management for both daily (temporary) maintenance activities and longer term construction activities to improve the safety of both the workers and travelers. While WSDOT already follows standard work zone procedures, additional work zone strategies can further improve safety for both travelers and workers:

- Implement speed control through work zones with the option of automated enforcement.
- Use portable VMS to warn drivers of upcoming work zones or to provide vehicle queue warnings caused by work zones.
- Coordinate with law enforcement to ensure drivers comply with work zone traffic management.
- Coordinate work zones both within WSDOT departments and with external agencies such as utilities or local agencies.
- Communicate delays, detours, lane configuration changes to travelers.
- Restrict lane closure and work hours to off-peak times.
- Advance connected vehicle applications used in work zones.
- Employ sensors that detect when a vehicle's trajectory could harm a worker and automatically notify the worker.
- Use automated attenuator trucks and mobile barriers to follow construction and maintenance crews in work zones.
- Install wireless PCMS for dynamic notification when static signs are not available.
- Implement third party applications to provide travelers with notifications about upcoming work zones or emergency vehicles, as well as providing incident managers with improved ways to manage fleets in real-time.

Example images from Haas Alert⁸:



⁸ Website: <http://haasalert.com>



Ramp Closures

Description

Ramp closures involve closing an on-ramp or off-ramp at an interchange with the intent of improving safety by improving interchange spacing. Closing a ramp can eliminate hazardous weave and merge areas and reduce congestion and collisions resulting from interchange spacing that does not meet performance expectations. Ramps can be closed by time of day (TOD), temporarily for an event, or permanently. If operated by TOD, ramp closure can work in conjunction with the ramp metering and ATM strategies. However, permanent closure would physically close the ramp and permanently eliminate the merge area.

Ramp closures will not move forward as part of this project. Due to the extensive impacts of a ramp closure, WSDOT will pursue an Interchange Justification Report (IJR) to investigate all the challenges that a closure presents. In addition, the Spokane Regional Transportation Council (SRTC) is in the process of a US 195/Interstate 90 Technical Study, that will be a multimodal plan to address safety, access, and operational issues in the US 195/I-90 corridor.

The analysis and results reported in this section focus only on the potential for a closure (either permanently or by time of day) to reduce crashes and improve safety.

Additionally, the project team recognizes that closing a ramp does not eliminate traffic, but routes it elsewhere in the system. This analysis does not account for the possibility of increasing crashes elsewhere in the system due to rerouted traffic.

Ramp closures will not be implemented with the currently available project funds.

WSDOT determined that a full Interchange Justification Report (IJR) will be necessary to further explore the impacts and benefits associated with a modification to an existing freeway access. An IJR is necessary when seeking to modify access to a freeway. Access revisions need to be approved by the Federal Highway Administration (FHWA) when an interstate facility is impacted.

The analysis reported in this memorandum seeks only to understand whether a ramp closure (either permanently or by time of day) has potential to improve traveler safety.

Evaluation Results

The benefits analysis provided as part of this study focused solely on the potential to reduce crashes to determine whether further evaluation is warranted for any of the locations. It did not take into account the potential for the shift in volume to increase crashes elsewhere, or any other socio-economic or environmental justice factors. The evaluation focused solely on the potential to reduce crashes in the ramp vicinity.

Based on the permanent ramp closure analysis, closures at four ramps stood out as having the most potential to improve corridor safety:

- Walnut EB On-Ramp or Monroe EB On-Ramp (only one of these ramps would be selected, not both)
- Division WB Off-Ramp
- Maple WB On-Ramp

Recommendations

Further evaluation is necessary before proceeding with any ramp closures. The next step would be to develop a full Interchange Justification Report (IJR), exploring the full impact of a closure. Elements of the document may include the impact to: nearby roadway networks, businesses, residents, environmental justice communities, emergency responder access, and other socio-economic factors.

Project Phasing

Ramp meters, wrong way notification, and merge and queue warning systems were selected as the priority strategies to implement as part of Phase 1. These projects will serve as building blocks to continue improving ITS operations the I-90 corridor. Once ATMS software is upgraded to accommodate ramp meters and the wrong way notification system, adding additional on and off-ramps to either system will be incremental.

In addition to the three projects listed above, WSDOT will continue to improve the Dedicated Responder program and will seek to implement the Instant Tow program through funding outside this grant.

PHASE AND PROJECTS	COST	B/C RATIOS	ANNUAL CRASH REDUCTION
Phase 1: Funded by Currently Programmed Funds			
Ramp meters – 6 Total			
EB: US-195, Walnut, Monroe, Division/Browne, Hamilton	\$2,000,000	2.1 to 2.9	9
WB: Division/Browne Wrong Way Notification – 13 off-ramps	\$2,500,000	1.6 to 2.5	<1
Improve signing near the I-90/US-195 EB Merge	\$400,000 (could be significantly greater depending on selected solution)	Variable (depends on strategy)	Variable (depends on strategy)
Total	\$4,900,000		> 10
Phase 1: Option to Substitute Above or Implement when Additional Funding is Available			
Queue Warning System upstream of Division westbound off-ramp	\$2,500,000	1.6 to 2.4	4
Phase 1: Implement as Funding Becomes Available			
Dedicated Responder (already implemented)			
Instant Tow	\$125,000	3.9 to 9.1	9
	20,000	11.0 to 15.4	3

As additional funding becomes available, strategies should be reevaluated for implementation to further enhance safety and operations along I-90:

- Expand ramp metering.
- Expand the wrong way notification system.
- Implement work zone management projects as feasible.
- Implement additional ATM structures. Once a segment is complete, the ATM could be used for variable speeds.